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# Development of the USSR's Eastern Coal Basins: A White Elephant?

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A Research Paper

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December 1985

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# **Development of the USSR's Eastern Coal Basins: A White Elephant?**

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**A Research Paper**

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This paper was prepared jointly by [redacted]  
[redacted] of the Office of Soviet Analysis and

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[redacted] Comments and queries are  
welcome and may be directed to the Chief,  
Economic Performance Division, SOVA, [redacted]

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December 1985*

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**Development of the USSR's  
Eastern Coal Basins:  
A White Elephant?**

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**Summary**

*Information available  
as of 1 December 1985  
was used in this report.*

Expanded coal use underpins the Soviet Long-Term Energy Program; planners are counting on coal, in conjunction with nuclear power, to provide nearly all new energy output once natural gas production levels off in the mid-1990s. Barring unexpected infusions of additional investment and technological breakthroughs, however, the USSR will probably have serious difficulty even approaching its goals for coal development—both in mining and in utilization.

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The Soviets are banking on the development of selected coal basins in the eastern USSR, but progress in overcoming technical problems related to the transport and use of coal from these basins—Kuznetsk, Kansk-Achinsk, and Ekibastuz—has been slow (see figure 1). The Soviets have focused largely on their ability to surface-mine vast amounts of coal cheaply, while underestimating the technical problems and costs related to the use of this very low quality coal. In short, eastern coal may be a white elephant—an energy reserve requiring research and investment funding far out of proportion to the gains achieved by meeting planned targets for coal output and use.

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In our view, the key bottlenecks to expansion of coal output and use will not be eliminated by General Secretary Mikhail Gorbachev's initiatives to tighten labor discipline and improve management. The major constraint to Moscow's coal program is slow progress in developing state-of-the-art coal-use and energy-transfer technologies—large-capacity lignite-fired boilers, coal-slurry pipelines, ultra-high-voltage electricity transmission systems, and synfuel plants. Mastering these technologies will require carefully planned, well-executed research and development and sizable capital outlays; investment in the coal and power industries would have to increase by one-half to provide the estimated 50 billion rubles required in the next 15 years to successfully fund the planned expansion of coal mining and use.

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Because of coal's enormous reserve base and because of dwindling proved reserves of oil and eventually even of gas, we judge that the USSR will continue to emphasize coal in its long-term energy plans. However, it probably will not devote the resources needed in the short term to get the coal industry moving toward its ambitious goals. The immediate investment needs of the oil and gas industries and modernization of the machine-building sector during 1986-90 will more likely take priority.

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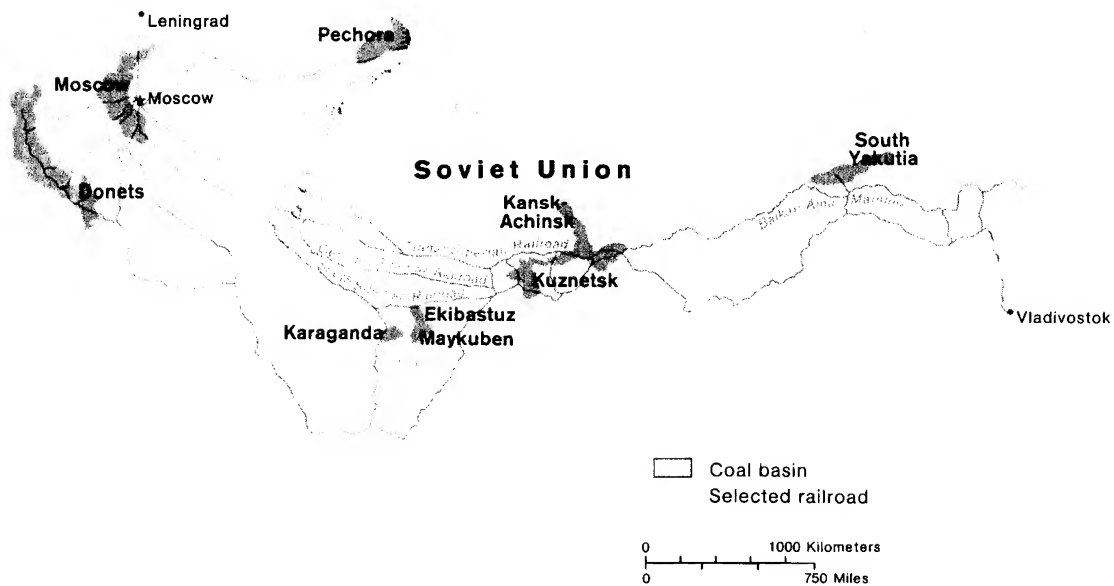
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**Figure 1**  
**Major Coal-Producing Basins**



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Eliminating the bottlenecks and moving coal to a fast track would involve long leadtimes and require up-front investment during 1986-90. Not meeting the short-term needs of the coal industry will make it very difficult for the industry to provide its expected share of increased energy production after 1995. In sum, we believe that coal production and utilization will probably increase only slightly—if at all—during the coming decade, leading to energy constraints beginning sometime in the 1990s. [ ]

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A failure to expand coal output and use would probably have the following consequences:

- An already tight balance between supply and demand for electric power in the Urals and Kazakhstan would be upset. An increase in the frequency and duration of power shortages during the 1990s would probably lower the output of key metallurgical, defense production, and agricultural facilities in these areas.
- Many power plants burning coal as their primary fuel would have to continue using more fuel oil than planned because of low coal quality and coal shortages. This situation would hamstring Soviet efforts to free up additional oil for alternative uses—an important consideration in view of declining oil output.
- Shortages of coking coal would continue to be a drag on steel production, adversely affecting Gorbachev's economic modernization program.
- Inadequate electric power supplies would slow the pace of natural resource exploitation along the Baikal-Amur Mainline railroad line in eastern Siberia during the latter 1990s. [ ]

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Time is running out on the opportunity to avoid these problems. Moscow could redesign the Long-Term Energy Program and, as an alternative to coal expansion during the latter 1990s, attempt further growth in natural gas output and larger-than-expected increments in nuclear energy production. To make these decisions, the Soviet leadership must focus on the longer term issues in energy and pull itself away from the day-to-day management that usually occupies its attention. With Gorbachev at the helm, this may be possible. [ ]

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An energy program with greater emphasis on gas and nuclear power would face different but still demanding problems:

- Further increases in gas output would accelerate depletion of reserves and risk a loss in ultimate recovery, a factor that Gorbachev has already warned against.
- The Soviet nuclear industry is even less prepared than the gas industry to replace coal as a long-term energy supplier. Moscow is already planning to substantially increase electricity generated by nuclear power stations in the European USSR. Soviet industry will have to substantially increase output of nuclear power plant components and equipment if the existing goals are to be met. Nuclear power could not be substituted for coal east of the Urals without even more sizable and costly additions to component-manufacturing capacity, major redesign work, and massive training of new personnel.

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Whether or not the Soviets elect to boost coal investment enough to achieve planned output, the coal industry's program in the coming decade will be characterized by high costs, bottlenecks, and technical problems that will probably require Western assistance. Coal-cleaning facilities have already been ordered from West German and Italian firms. An Italian firm has recently received a contract to provide process technology and engineering services for a 250-km coal-slurry pipeline to transport 3 million tons of West Siberian coal annually. For the last five years, the Soviets have been soliciting assistance—primarily through technical information exchange agreements—in coal liquefaction technology from Western firms.

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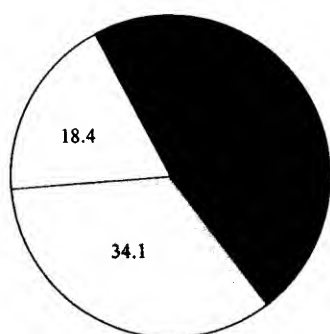
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**Figure 2**  
**USSR: Energy Production, 1970-90**

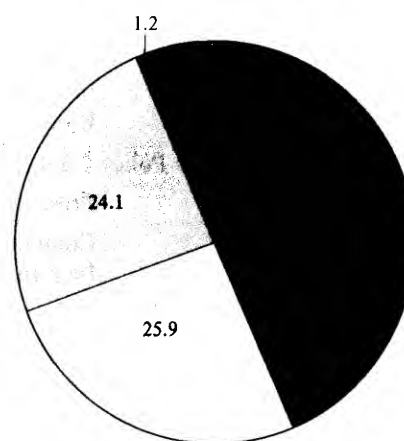
Million tons standard fuel  
 (percent)

Oil  
 Coal  
 Natural gas  
 Nuclear  
 Other<sup>a</sup>

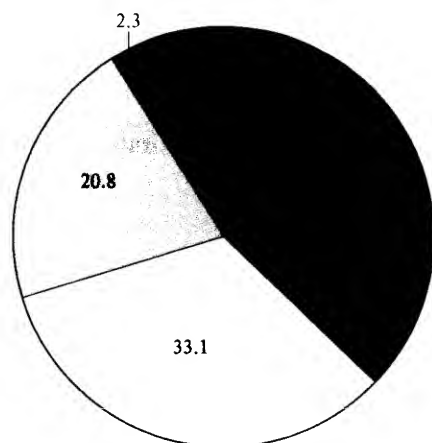
1970  
 Total: 1,269



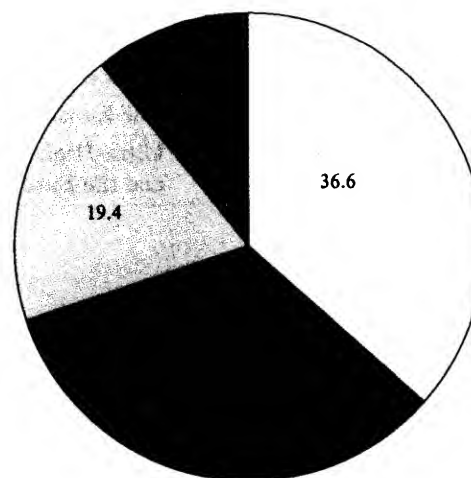
1980  
 Total: 1,980



1985<sup>b</sup>  
 Total: 2,199



1990 plan  
 Total: 2,726



<sup>a</sup> Other includes: hydro, peat, shale, and fuelwood.

<sup>b</sup> Estimated.

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## Development of the USSR's Eastern Coal Basins: A White Elephant?

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### Changing Role of Coal in the Soviet Energy Scene

Coal, once the USSR's main energy source, was overtaken by oil in the late 1960s and by gas in the 1970s (see figure 2). Soviet energy planners, however, are counting on additional coal production, in conjunction with nuclear power, to satisfy nearly all of the growth in energy demand by the year 2000.<sup>1</sup> This goal is embodied in the USSR's Long-Term Energy Program, published in 1984. The major expansion of coal production called for in this program will depend on sizable increases in output at selected large surface mines and the development of reliable, cost-efficient means of transporting and utilizing energy from coal.

The Power Ministry is planning to construct substantial new capacity in coal-fueled power stations during 1986-90 and beyond. At least 11 major coal-fired thermal power plants and many smaller plants are in the building or planning stages. The Soviets expect this capacity to be partially operational or completed by 1990. Moreover, they are planning to build five major coal-fired mine-mouth power plants in the Kansk-Achinsk and Ekibastuz coal basins after 1990. Most of the electric power from these new plants is intended for use in the Ural and Kazakhstan regions, where the present balance between the supply and demand for electric power is tight. The Soviets also hope to convert some electric power plants that are presently burning fuel oil to coal or gas use. They plan to further refine the "saved" fuel oil to satisfy the growing demand for lighter products such as gasoline and diesel fuel.

### Trends in Underground Mining

Growth in coal output was, until the late 1970s, provided largely by expansion of underground mining. This option, however, is no longer practical. Coal

<sup>1</sup> The "Draft Guidelines for Economic Development During 1986-90 and Through 2000" also call for construction of large coal-fired power plants. The Draft Guidelines, however, do not provide output projections beyond 1990 and do not discuss the relative roles of the different fuels during this time frame.

production at most of the major basins relying on underground mines is now essentially stagnant. From 1980 to 1984, the total annual output from underground coal mines fell by about 30 million tons, to about 418 million tons (see figure 3).

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Coal production in the Donets basin—the USSR's largest producer—declined from a peak of 225 million tons in 1976 to about 196 million tons in 1984 and will continue to fall during the balance of the 1980s. After more than two centuries of mining, the easily exploitable reserves in this basin have been exhausted. In terms of mine depth, seam thickness, and methane concentrations, most of the Donets mines would no longer be considered proved reserves by Western standards. The average depth of the Donets mines in 1982 was about 605 meters—eight times as deep as the average US coal mine. The average thickness of Donets coal seams in 1980 was less than 1 meter—three-fourths as thick as the seams being worked a decade earlier and about one-half as thick as average coal seams in the United States. Moreover, most of the Donets mines have dangerously high concentrations of methane.

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Similar problems underlie declining production at other Soviet underground coal basins. Output from the Karaganda basin has been flat since 1980. Production from the Moscow basin—where the mining conditions are even more severe than in the Donets basin—has dropped substantially since production peaked in 1960.

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### Trends in Surface Mining

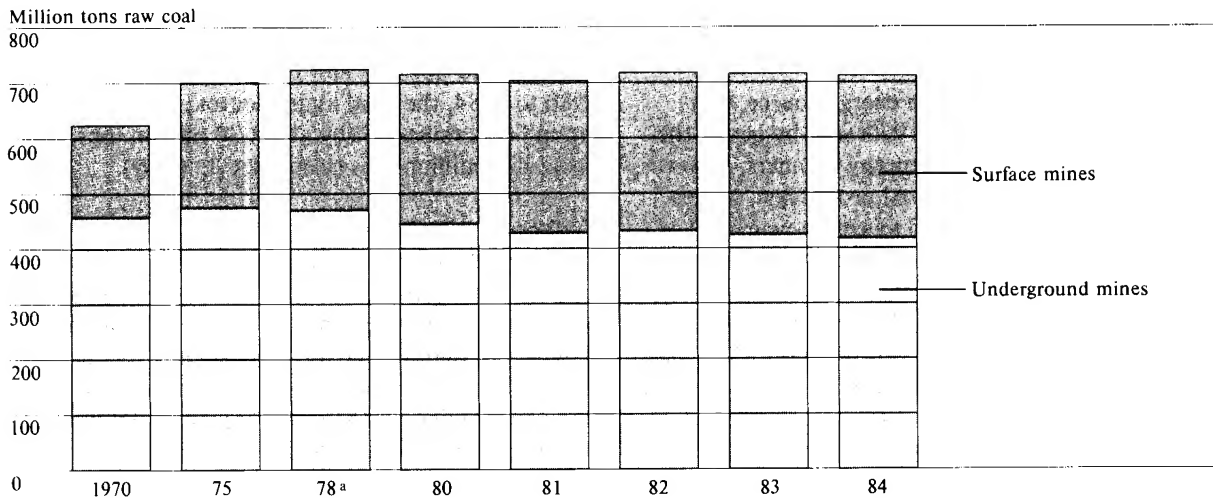
Not surprisingly, Soviet energy planners have opted not to seek growth of coal output through high outlays on costly mining innovations and new capacity in underground operations. Instead they have embraced the goal of expanding surface mining as the most cost-effective way to boost coal output. The share of

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**Figure 3**  
**USSR: Stagnating Coal Production, 1970-84**



<sup>a</sup> Peak production.

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surface-mined output in total coal production increased from roughly one-fourth in 1970 to about two-fifths in 1984. During this period, the coal industry boosted the annual output of surface mines from 167 million tons to 294 million tons. Growth of coal production from this activity has slowed considerably in the last decade—dropping from an average annual rate of nearly 5 percent during the 1970s to about 2 1/2 percent. [redacted]

Coal output from surface mining grew rapidly in the 1970s because of the working of new mines and because relatively simple solutions were available for the attendant problems in coal transportation and consumption. Coal production from new mines in Kazakhstan, West Siberia, and the Soviet Far East was accommodated by relatively short hauls on existing rail systems. The coal was used in small-to-medium-sized boilers at existing and newly built power plants where proven technology could be

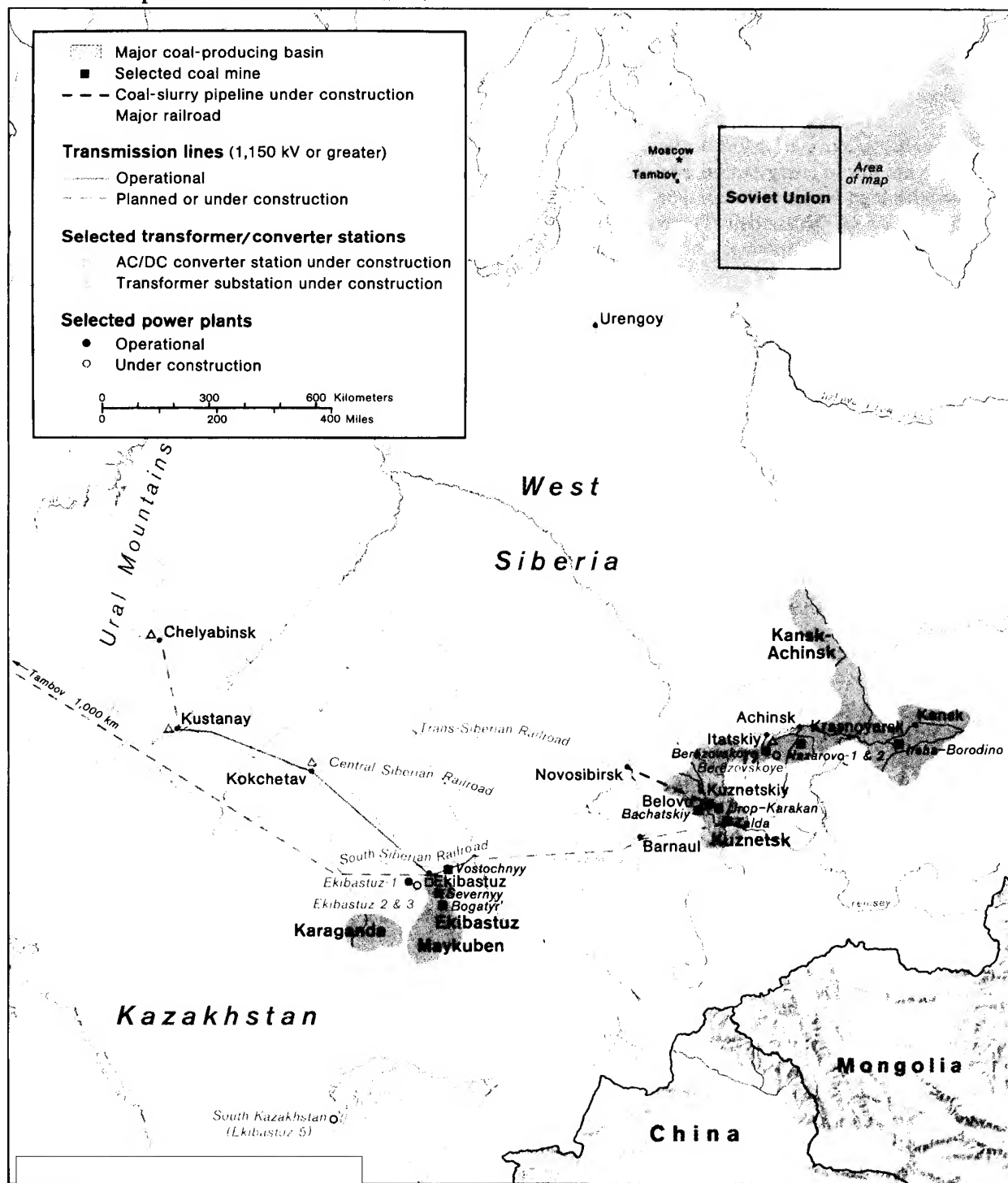
readily adapted to burn the lower quality coals from the new surface mines. [redacted]

In the 1980s, however, the Soviets began to push a new, more complex, and costlier approach to surface mining and coal use. The expansion of surface mining is being concentrated at a few mines in a small number of coal basins. Total annual output—from both surface and underground mines—has been hovering around 715 million tons, while long-term goals call for yearly production of nearly 1 billion tons by the year 2000. Interim goals are no less ambitious: nearly 800 million tons by 1990 and about 900 million tons by the mid-1990s. Virtually all of this growth is to come from surface mines east of the Urals, with the Kuznetsk, Ekibastuz, and Kansk-Achinsk coal mines designated as the main producers (see figure 4). [redacted]

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**Figure 4**  
**Soviet Development of Eastern Coal Basins**



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### The Key Eastern Basins: Energy Possibilities and Exploitation Headaches

To move coal back to the forefront of energy production and use, the Soviets must find and implement technological solutions to two key problems:

- *Low quality of the coal.* Most of the USSR's coal reserves are low in energy value, comprising lignites (often with high moisture content) or subbituminous coals with a high ash content. These coals require unique approaches to mining, transportation, and combustion.
- *Distance.* The major coal deposits that the Soviets want to develop are thousands of kilometers from the industries and population centers most in need of the energy. Consequently, low-cost energy transportation is essential to the viability of any coal-development scheme. [ ]

There are a number of technology options Moscow can employ, singly or in combination, at each of the key coal basins. These include new approaches to problems in coal mining and transportation, coal combustion, and synthetic fuel (synfuel). We project, however, that the Soviets will continue to concentrate their efforts on a few technologies (some requiring purchases from the West) and to apply a relatively narrow selection of technologies at each coal basin they want to expand. The chief advantage of this strategy is to concentrate resources on the earliest possible commercialization of a technology. But there are two major drawbacks to the narrow focus of coal technology development—increased risk that an inappropriate technology will be pushed for too long or that a superior technology will not be given a chance. [ ]

Current Soviet planning for coal technologies calls for widespread use of bucket-wheel excavators for high-volume surface mining; application of coal-slurry pipelines only to the transportation of the relatively high-grade Kuznetsk coal; extensive use of mammoth, mine-mouth power plants with ultra-high-voltage (UHV) electricity transmission from the Ekibastuz and Kansk-Achinsk power plants to distant consumers; and exploitation of the synfuel alternative only at

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### *When Consumption Becomes a Production Constraint*

Initial capacity for producing 4.5 million tons of coal [at a mine in the Kansk-Achinsk basin] was slated for coming on line this year and was timed to coincide with the startup of the first 800-MW unit of the power plant. This linkage has become a stumblingblock to mine construction. Assembly of the boiler still has not begun and will require about 20 months to complete. . . . The gigantic coal-mining machine will inevitably be idled.

Pravda, 26 August 1985

[ ]

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Kansk-Achinsk. Appendix A summarizes these technology options and indicates the status of each technology both in the USSR and in the West. [ ]

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Development plans for each of the three key eastern basins call for a rapid expansion of production through the use of mining equipment that can efficiently move large quantities of coal and equally large volumes of the earth and rock overburden that covers coal seams. This equipment often needs major adaptations to local mine conditions and, moreover, requires careful maintenance. The Soviets have not been able to meet these requirements efficiently, and key equipment regularly operates at less than 30 percent of its intended capacity. For example, a crew leader at a mine in the Kuznetsk basin has reported that nearly every piece of mining equipment arriving from the manufacturing plant requires major adjustments before operation. [ ]

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Mining more coal is only part of the problem. Coal production from Ekibastuz and Kansk-Achinsk is being constrained by the failure to bring the accompanying power plants on line as scheduled. In both basins, mines were developed as suppliers for mammoth power complexes of 4,000 to 6,400 megawatts (MW) capacity to be linked, in turn, to distant

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demand centers via UHV transmission lines. However, power industry managers have failed—in part because of the very low quality of the coal being supplied—to move these coal-use technologies from design concepts through the various stages of development necessary for commercial application. Soviet UHV technology is also years behind schedule. If the USSR is to meet the presently postulated goals for energy production from surface-mined coal, the power industry must put these systems into commercial operation during the 1980s and 1990s, largely without adequate testing for working out the bugs and improving the designs. [ ]

#### **Kuznetsk Coal: Good Quality But Poor Location**

The coal output of the Kuznetsk basin has leveled off in recent years, and we do not foresee a substantial increase in coal production there before 1990 (see appendix B). Press reports indicate that, because of inadequate investment for modernizing old mines and opening new underground mines at Kuznetsk, it will be difficult—despite the development of new surface mines—to raise the basin's annual production from about 145 million tons in 1984 to 160 million tons by 1990. [ ]

After 1990, however, Kuznetsk output may increase quickly if the Soviets continue to develop surface-mining operations and can provide adequate transportation facilities. To prevent transportation bottlenecks, they might resort to high-capacity, long-distance coal-slurry pipelines. The Soviets have little experience in building and operating coal-slurry pipelines, however, and probably could not successfully complete the pilot pipeline currently under construction without substantial Western assistance.<sup>2</sup> Western assistance for this 250-km, \$150 million pipeline may be a precursor of sales to support a much larger project in the late 1980s and early 1990s—a 3,000-km, \$1-2 billion pipeline. [ ]

<sup>2</sup> The 70-percent-coal water-based slurry technology being sought by the USSR requires that the coal have low ash and low inherent moisture. We believe that this makes Kansk-Achinsk (about 40 percent inherent moisture) and Ekibastuz coals (40 percent or more ash) unlikely candidates for a pipeline system to supply slurry for direct burning. It may be possible, however, to use methanol rather than water as a slurry medium for high-ash and high-moisture coals. Soviet production of methanol is currently about 2 million tons per year—far short of the 12-15 million tons of methanol that would be required. [ ]

#### **Ekibastuz Coal: More Rock Than Coal?**

Although Ekibastuz development is the furthest along of the current major Soviet coal projects, it is well behind plans (see appendix C). The long-term prospects for this basin will improve considerably when Western-manufactured coal-blending plants—purchased in 1984—are put on stream and when Soviet power-plant researchers create improved boiler designs to cope with the high ash content (40 to 60 percent) of the coal. These improvements to coal usage are, however, unlikely to make a full impact until the 1990s. [ ]

For the foreseeable future, Ekibastuz coal output will be closely tied to the fuel requirements of the large power plants being built near the mines. Power-plant constructors are now adding one 500-MW steam turbine per year at these plants, only half the planned rate of expansion. At this rate of construction, coal usage can expand only 2 million tons per year. The Soviets could more than double growth of demand for Ekibastuz coal by the mid-1990s if they can install technologies to simplify use of high-ash coal. The 1,150-kilovolt (kV) alternating current powerlines nearing completion—one to the Urals and another to the Kansk-Achinsk basin to provide electric power for the mines and power plants under construction—will probably provide enough capacity to accommodate expanded electricity output from mine-mouth power plants through the mid-1990s. After that time, however, expansion of the Ekibastuz complex will be constrained unless the 1,500-kV direct-current powerline to the European USSR is operational (appendix E discusses UHV technology in more detail). The Soviets are likely to turn to Western suppliers for some of the components on this powerline. [ ]

#### **Kansk-Achinsk Coal: Forty Percent Water**

We believe development of the Kansk-Achinsk basin will proceed at a much slower pace and on a much smaller scale than originally planned (see appendix D). The Soviets have made little progress to date in developing 500-800-MW boiler technology to use Kansk-Achinsk's high-moisture coal. They originally planned to build eight to 10 large mine-mouth power plants at Kansk-Achinsk. Recent press reports

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indicate current plans to build only two to three plants. Because shipment of large volumes of Kansk-Achinsk coal to the Urals and farther west is uneconomical, development of the basin is necessarily tied to the building of these large power plants and to successful application of UHV technology for transmission of the generated power. [ ]

Soviet efforts to develop synfuel technology are similarly proceeding at a slow pace. Although the Soviets have recently completed a 5-ton-per-day (coal input) liquefaction pilot plant, the technology must still be proved and scaled up to a commercial level.<sup>3</sup> Given Soviet difficulties in developing some secondary oil-refining processes—common in the West and less sophisticated than the coal-conversion process—we believe that the liquefaction program will progress slowly at best. The Long-Term Energy Program, however, indicates plans to liquefy Kansk-Achinsk coal commercially on a large scale during the 1990s. If the Soviets fail to develop coal-conversion technology, output of the basin will probably be constrained by low demand and reach about 100 million tons rather than the planned 200 million tons in 2000.

### Energy Policy Choices and Implications

In addition to the technological obstacles, the need for immediate response to the decline in oil output will further constrain Moscow's latitude in dealing with coal development. Because there is no substitute for oil in many critical uses, Gorbachev's energy policy will need to ensure adequate oil supplies before it can focus on the longer term role of coal.<sup>4</sup> We estimate, for example, that, to keep oil output from falling below about 11 million barrels per day by 1990, investment in the oil industry during 1986-90 would

<sup>3</sup> Successful operation of a pilot plant does not guarantee that the process will work. Bugs encountered in scaling up the design have to be eliminated, adjustments made, and downtimes shortened; in general, the entire process has to be better understood and made more predictable. [ ]

<sup>4</sup> The substitution of other fuels—specifically coal and gas for oil—can be readily undertaken at boilers and furnaces where the primary intent is to generate heat. For many critical products, such as fuels, lubricants, synthetic rubber, and plastics, however, there are few acceptable substitutes for petroleum products derived from refining crude oil. [ ]

need to increase by about 45 billion rubles—nearly doubling the 1981-85 spending. [ ]

### Prospective Investment Requirements for Coal-Based Energy

Annual investment in the coal and electric power industries would have to increase by more than 50 percent from the present level if Moscow tries to implement its plans for coal development. We estimate that investment for open-pit coal mines, mine-mouth power plants, UHV powerlines, and a commercial synfuel industry will require a total of about 50 billion rubles by the year 2000.<sup>5</sup> This estimate is based on [ ]

[ ] comparable US synfuel development. This investment, which is equivalent to about 3.3 billion rubles per year for the balance of the century, is about three times the current investment rate for these projects. [ ]

Vigorous implementation of the eastern coal projects essentially provides the only way to achieve long-term goals for production of coal-based energy (see inset). This course of action would result in drastic changes in the pattern of investment allocation within the coal and electric power industries. The Soviets currently invest about 2.5 billion rubles a year in the coal industry. [ ] only one-fifth of this spending is now going to the coal basins selected for expansion. The electric power industry is probably spending an even smaller share of its 4.5-billion-ruble annual investment on projects linked to eastern coal, because the bulk of its operations lies west of the Urals, particularly the expensive commitment to nuclear power. [ ]

The largest share of new investment in coal, 27 billion rubles, will be needed to launch a synfuel industry based on Kansk-Achinsk coal. Investment of this amount would probably permit the Soviets annually to mine an additional 50 million tons of Kansk-Achinsk coal and process it into 10 million tons of synthetic

<sup>5</sup> The 50 billion rubles is our estimate of needed new spending during 1985-2000 to implement coal expansion. This projection represents the sum of separate investment estimates for the planned development at Kuznetsk, Ekibastuz, Kansk-Achinsk, and at smaller coal projects. [ ]

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**Improvement on the Cheap?**

*Gorbachev is advocating managerial reforms in Soviet industry to boost productivity and cut costs without adding to investment outlays. Coal development could benefit from this approach to some degree but, in our view, the key bottlenecks to coal expansion will not yield to a reform movement. Managerial tinkering with incentives, worker training, and maintenance programs could result in better utilization of mining equipment and may result in delivery of cleaner coal. Incentives for rail workers, upgraded on/off loading facilities, and enforcement of penalties for freight mishandling might increase the efficiency of coal transport by rail. Nevertheless, the major constraints to the coal program are in the coal-use and energy-transfer categories. The Soviets need better boiler designs, more efficient coal use, and smoothly functioning UHV systems—none of which will come easily or cheaply. These improvements will require carefully planned and well-executed research and development (probably involving Western technology) and sizable capital outlays.*

liquids. Another 17 billion rubles will be required to implement plans for construction of mines and electricity production and transmission facilities at Ekibastuz, Kansk-Achinsk, and Kuznetsk. About 3 billion rubles will be needed to put new mines into operation at the smaller coal projects scheduled for the Soviet Far East.<sup>6</sup>

<sup>6</sup> The 27-billion-ruble synfuel investment equates to: 1 billion rubles in scale-up research for commercial-plant technology, 1 billion rubles in coal-mining infrastructure to produce 50 million tons of coal, and 25 billion rubles in synfuel plant and equipment that could process 50 million tons of coal into 10 million tons of synfuel products.

We estimate that 17 billion rubles will be needed during 1986-2000 to realize plans for Kuznetsk, Ekibastuz, and Kansk-Achinsk. According to Soviet technical journals, only 3 billion rubles of the 20 billion rubles required has been spent.

Kuznetsk mines and two slurry lines (one short and the other 3,000 km long) will cost nearly 2.8 billion rubles; Ekibastuz mines, power plants, and UHV lines will require 10 billion rubles investment; and Kansk-Achinsk mines, power plants, and UHV lines are targeted for 7.2 billion rubles of spending.

Soviet long-range planning also envisions dozens of smaller projects contributing to coal development—South Yakutsk, for example. Investment at these smaller deposits will probably total 4 billion rubles by the year 2000. Over 1 billion rubles has already been spent, most of this at the Neryungri Mine in the South Yakutia project.

Another perspective on investment requirements for coal expansion is their size relative to overall energy investment. During 1981-85, Moscow will probably have invested some 140 billion rubles in energy. The nearly 50 billion rubles of new investment that we project for eastern coal projects represents a substantial increase in total energy investment, even though this spending is likely to be stretched over the next three five-year plans.

**Competition With Other Energy Programs for Scarce Investment Resources**

To be successful during the remainder of the 1980s and into the 1990s, the strategy of coal resurgence must not only incorporate new technologies but also compete with natural gas and nuclear energy in terms of reliability and economy. The competition for investment resources will be keen as Moscow pursues costly projects in the oil and gas sector: offshore oil development in the Caspian and Barents Seas; sour gas development at Astrakhan' and Karachaganak; and development of West Siberian gasfields that are located north of Urengoy in more hostile environments.

The Long-Term Energy Program recognizes this competition in its schedule for the development of energy sources. Natural gas has been endorsed as the fuel that is to provide growth in total energy at least through the mid-1990s, when gas output is expected to level off. Coal and, to a lesser extent, nuclear power are scheduled to meet the subsequent growth of total energy demand in the economy, eventually surpassing the contribution of natural gas.

Of the three major energy sources, coal is clearly the laggard. Natural gas output is growing robustly, and the Soviets are mustering resources to convert facilities from oil and coal fuels to gas so that industrial growth can be maintained. Electricity output at nuclear plants has increased at an average annual rate of over 20 percent since 1979, even though nuclear energy expansion continues to be hampered by bottlenecks in construction and component manufacturing (see inset).

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**Performance of the Soviet Nuclear Industry**

*The performance of the Soviet nuclear industry merits a mixed review. While the USSR has achieved greater success than many other countries in expanding the nuclear contribution to electricity supply, the Soviets are well behind their goals for construction and power production at nuclear plants. During 1981-85, 15 of 22 planned reactors were put on line; generating capacity increased by 13,820 megawatts instead of the plan minimum of 21,320 megawatts. Nevertheless, power output at nuclear plants has grown from 58 billion kilowatt-hours in 1979 to 142 billion in 1984. By June 1985, the Soviets had 14 nuclear power plants (38 reactors) on line with a total capacity of 25,312 megawatts. The current output from these plants accounts for about 11 percent of the USSR's electricity generation.* [ ]

*The key elements limiting the Soviet nuclear program are shortfalls in component fabrication and construction bottlenecks. The showcase component manufacturing plant, Atommash, has failed to meet its production goal of eight reactor systems per year; annual output is two systems, at best. The component manufacturing slippages have contributed to the construction delays plaguing the USSR's nuclear program. Although the Soviets recently built a nuclear power plant and put its first reactor on line in five years, most reactors take eight to 11 years to complete.* [ ]

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Coal still retains some advantages over gas and nuclear power in Soviet long-range energy policy. If Moscow should attempt to back away from coal and look to either gas or nuclear energy as the main long-term supplier, a major reorganization would be needed. The gas industry (both producers and pipeline layers) would need to step up its already high-gear operations. The current strategy of intensively developing a single gasfield so as to reach peak output within five years after development begins would probably be pushed aside in favor of even more rapid expansion. This acceleration of gas development would risk repeating the mistakes of the oil industry, where too-rapid reserve depletion meant that ultimate recovery was sacrificed to boost current output. [ ]

The Soviet nuclear industry is even less prepared than the gas industry to replace coal as a long-term energy supplier. The nuclear industry's infrastructure was set up in the early 1970s to provide for growth in electricity demand only in the European USSR, and it has yet to meet these plans. Nuclear power could not be substituted for coal east of the Urals without sizable, costly additions to component-manufacturing capacity, major redesign work, and massive training of new construction and operations personnel. [ ]

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Gorbachev has left some room for accelerated coal development in his economic agenda. Coal development may benefit from his call for modernization in machine building, a shift in emphasis from production volume to better quality, and the push for technical progress in Soviet industry. Coal development stands to gain from a large increase in machine-building investment and the focus on technical progress, because open-pit coal mining and electricity generation and transmission are equipment-intensive operations. Similarly, a drive to improve product quality could help the coal industry mobilize resources for cleaning and upgrading more coal. [ ]

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At the same time, Gorbachev has also pressed for changes that could rule out a timely coal resurgence. Prospects for growth of coal output probably will dim if Gorbachev pushes energy conservation at the expense of production, if some coal development projects are mothballed as Gorbachev has threatened to do with assets "frozen in Siberia," and if the campaign to retool existing enterprises draws resources from the eastern USSR back into the western industrial heartland. Although eastern coal projects are not currently victimized by these proposals, they certainly are at risk. [ ]

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Backing for investment allocations that would enable coal to become the prime Soviet energy source sometime after the mid-1990s will be hindered by coal's reputation for unreliability. During 1981-85, declining coal quality caused major problems for the electric power and metallurgical industries, the main coal

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users. Many power plants had to supplement coal firing with oil or natural gas (or substitute these for coal entirely), because the energy value of the coal being supplied to them had dropped. At a large number of power plants, the poor coal quality caused breakdowns of key equipment, forcing the plants to shut down for repairs. In the metallurgical industries, steel production was particularly hard hit by coal shortfalls and quality deterioration. Backers of the coal strategy can argue that new technology in mine-mouth power plants and, eventually, synfuel development will improve the quality of energy derived from coal. The promised improvements lie in the future, however, while the reliability of natural gas and electricity from nuclear power plants is a present and continuing reality. [ ]

The competition among energy suppliers for new resources is likely to reach an important turning point by 1990. At this juncture, Soviet energy policy makers will need to make critical resource commitments among the coal, natural gas, and nuclear options that will largely determine the shape of the USSR's energy supply after 2000. The leadtimes for major project completion in all the energy industries dictate that large new programs be started 10 to 15 years in advance of needs. The remainder of the 1980s will therefore be a trial period for eastern coal development, a time when schemes for large-scale surface mining and mine-mouth power generation must prove themselves viable or risk losing out in the bidding for resources. [ ]

### Output Projections

Moscow could put the coal industry in a substantially better position to achieve growth if it were willing to boost the resources going to coal projects. We have estimated the likely range of coal output in the next two decades by considering the two basic policy choices: favoring coal expansion or forgoing coal expansion (see table). In the first case, we projected that Moscow would favor coal expansion by:

- Actively acquiring Western assistance in most of the key technologies: coal combustion, UHV transmission, slurry transportation, and synfuels (see inset).

**Table 1** *Million metric tons of raw coal<sup>a</sup>*  
**USSR: Coal Output Projections, 1985-2000**

	1985	1990	1995	2000
<b>Soviet goals<sup>b</sup></b>				
Total	726	780-800	850-900	910-1,000
Underground mines	411	400	400	400
Surface mines	315	380-400	450-500	510-600
Of which:				
Kuznetsk	54	75	100	150
Ekibastuz	78	105-115	130-145	150-170
Kansk-Achinsk	49	70	120-135	170-200
<b>Moscow favors coal expansion<sup>c</sup></b>				
Total	721	715	760	805
Underground mines	411	375	340	305
Surface mines	310	340	420	500
Of which:				
Kuznetsk	54	62	80	100
Ekibastuz	76	86	105	130
Kansk-Achinsk	41	54	84	110
<b>Moscow forgoes coal expansion<sup>d</sup></b>				
Total	721	700	705	705
Underground mines	411	375	340	305
Surface mines	310	325	365	400
Of which:				
Kuznetsk	54	60	67	72
Ekibastuz	76	86	96	106
Kansk-Achinsk	41	48	54	60

<sup>a</sup> Gross output of run-of-the-mine coal.

<sup>b</sup> Based on Soviet Long-Term Energy Program [ ]

<sup>c</sup> Indicates likely outcome if Moscow makes a substantial resource commitment to coal projects and resolves technical problems.

<sup>d</sup> Indicates likely outcome if Moscow continues to hold back on resource increases to coal projects.

- Substantially increasing investment allocations to the coal projects.

If goals to expand coal output are pursued aggressively, production at surface mines could be increased by

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### *A Role for Western Technology?*

*If the USSR decides to make the commitment necessary to expand coal output, we believe that Western equipment and technology will play a growing role in the effort and could become major factors affecting the speed and magnitude of Soviet coal development. The inadequacy and slow development of the USSR's coal technology and equipment have been increasingly criticized by Soviet energy experts in press and industry journals. Some of these specialists have gone further and noted that Western approaches to the commercialization of coal technology, such as coal liquefaction, are superior to those of the USSR.*

*Western coal expertise could be employed in four areas: mining, transportation, combustion, and coal liquefaction. Currently, the Soviets are making only limited use of Western mining equipment and are negotiating for a small-scale application of slurry transportation technology. In the key technologies of UHV electricity transmission (energy transportation) and coal combustion, Moscow thus far has relied on domestic capabilities.*

*The best Western source of UHV technology is the Swedish firm ASEA (see appendix E). Swedish expertise, particularly in the critical area of component manufacture, has been incorporated in half of the*

*direct-current UHV transmission lines in operation worldwide. Many other Western countries have demonstrated technical competence in selected aspects of UHV transmission, but ASEA is clearly the world leader.*

*ASEA to be at least five years ahead of US manufacturers. If the Soviets turn to Western suppliers for much of their UHV technology needs, purchases could amount to several hundred million dollars by the 1990s.*

*Moscow is beginning to purchase the coal-slurry technology that it hopes will ease the long-distance transportation burden and may even simplify coal combustion. Consortiums that include firms from the major West European countries, Japan, and the United States are bidding for initial contracts worth \$100-200 million. An Italian firm will be supplying most of the process technology and engineering services. If this technology proves viable in the USSR, follow-on sales of components for high-volume slurry lines could range up to \$2 billion. Among the possibilities discussed by Soviet slurry specialists are export-pipeline projects based on the use of compensation deals to facilitate technology purchases. Although such lines would not be feasible until the 1990s, they probably will be advanced by Moscow in negotiations for coal-slurry technology.*

*nearly 200 million tons to boost total output to about 800 million tons by the end of the century.*

*The USSR's coal output would stagnate at the current level of about 700 million tons if Moscow were to forgo coal expansion and favor other energy sources. In this case foreign technology would still be important to the solution of some problems (such as slurry transportation of Kuznetsk coal), but application of Western know-how to the full range of technological constraints would be unnecessary.*

*Indications that Gorbachev has decided on and gained consensus for a substantial resource commitment to eastern coal could include:*

- A 1986-90 economic plan that favors coal over oil and gas in terms of increased investments.*
- Negotiations in earnest with Western firms on technologies for coal combustion, transportation, and synfuels.*
- Identification of coal development as a beneficiary of the upcoming industrial modernization drive.*

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Because of coal's enormous reserve base and because of dwindling reserves of oil and eventually even of gas, we judge that the USSR will continue to emphasize coal in its long-term energy plans but will probably not devote the resources needed in the short term to get the coal industry moving again. The immediate needs of the oil and gas industries and plans to modernize the machine-building sector during 1986-90 will require substantial investment. The nature of the bottlenecks holding down coal production will not yield to easy, short-term solutions. Eliminating the bottlenecks and moving coal to a fast track will require long leadtimes and large investment up front. If Gorbachev ignores the needs of the coal industry in the short term, coal production will likely continue to stagnate (or increase only slightly during 1986-90) and the coal industry will probably not be ready to provide nearly all of the growth in energy production after 1995. [ ]

- Shortages of coking coal would continue to hold down steel production, adversely affecting Gorbachev's economic modernization program.<sup>7</sup>
- If the Soviets decide to accelerate development of natural resources (iron ore, copper, phosphate, timber) along the Baikal-Amur Mainline railroad (BAM), inadequate electric power supplies would curtail the pace of exploitation during the latter 1990s—particularly for the more power-intensive industries. [ ]

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<sup>7</sup> The Soviets, however, could turn to the West for solutions to the coking coal crunch. Imported state-of-the-art steel production technologies that do not require coking coal or imports of coking coal could be used to keep steel output growing. [ ]

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#### Impact on the Soviet Economy

Less-than-planned growth in coal output during 1985-2000, which seems likely, would adversely affect the Soviet economy in the following ways:

- Stagnant coal output would upset an already tight balance between supply and demand for electric power in the Urals and Kazakhstan. An increase in the frequency and duration of power shortages (brownouts and blackouts) during the 1990s would probably have adverse consequences for the output of key metallurgical, defense production, and agricultural facilities in these areas.
- Many power plants burning coal as their primary fuel would have to continue using more fuel oil than planned because of low coal quality and coal shortages. This situation would hamstring Soviet efforts to free up additional oil for alternative uses—an important consideration in view of declining oil output.

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## Appendix A

Technology Options for  
Soviet Coal Development

Technology	Applications	Advantages	Drawbacks	Status of Soviet and Western Technology
<b>Mining</b>				
High-volume surface-mining equipment	Nominally all coals, but geology of certain basins limits effectiveness.	Least costly approach to large-scale production.	Capital-intensive; demands superior mine planning, implementation, and maintenance to maximize equipment utilization.	Technology is not very sophisticated, but Soviets must import large volume of equipment from East Germany.
<b>Transportation</b>				
Coal-slurry pipelines	Transportation of good-quality coal, such as Kuznetsk.	Lowers transportation costs, eases rail bottlenecks. Advanced slurry combustion technology could improve boiler operations.	Present technologies cannot handle low-quality coals such as those of Ekibastuz and Kansk-Achinsk.	Soviet technology at low level, especially for direct-burning systems. In West, technology for 50-percent slurry system proven commercially; 70-percent (direct-burning) slurry system developed but untested on a commercial scale.
Coal-methanol-slurry pipelines	Transportation of all coals.	Potential advantages over water slurry: low-temperature operation, increased energy value of coal, methanol medium valuable for subsequent uses. Particularly good for lignite transport.	Sizable investment in development and facilities construction, including large increase in methanol output.	Major engineering hurdles in dealing with corrosive effects of methanol and with properties of coal-methanol slurries in transportation, storage, and combustion must still be resolved. Little worldwide experience. Possibility of synthesizing methanol from coal (late 1990s at the earliest).
Exotic pipelines: carbon dioxide slurry, pneumatic capsule	Transportation of all coals.	Reduces or eliminates problems of slurry-medium disposal. Could work well for lignite coal or for arid parts of Kazakhstan (Ekibastuz) where water slurries are ruled out.	Will require a sizable research effort, large investments. Major technical hurdles.	Soviets have done only lab tests. A US firm is marketing a carbon dioxide slurry technology for use by 1990.
UHV electricity transmission at 1,150 kV AC	Large power transfers over medium-to-long distances (4,000 MV up to 1,500 km) from mine-mouth power plants in Ekibastuz.	Lowers cost, cuts losses on long-distance transmission. Can improve quality of electricity supply to users.	Requires electrical components of superior quality and often of new design.	No field experience in USSR or in other countries. Soviets will probably complete construction of a 1,150-kV AC line by 1990.

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### Technology Options for Soviet Coal Development (continued)

Technology	Applications	Advantages	Drawbacks	Status of Soviet and Western Technology
UHV electricity transmission at 1,500 kV DC	Large power transfers over long distances (6,000 MW up to 2,500 km). Generation at mine-mouth power plants in Ekibastuz, Kansk-Achinsk.	Lowers cost, cuts losses on long-distance transmission, even when compared to UHV-AC systems. Can improve quality of electricity.	Major investment required. High-technology electrical components needed. Costly transformer stations preclude servicing multiple demand centers.	Soviet construction of a 1,500-kV AC line was halted in 1982. Some reports that construction may resume. Swedish expertise, particularly in the critical UHV-DC thyristor technology, is the world's best.
UHV electricity transmission above 2,000 kV	Large power transfers from central Siberia to European USSR (1,000 MW up to 5,000 km).	Could be used to directly link the major demand centers in European USSR with mine-mouth power plants in Siberia.	Very substantial investment in R&D and test facilities required.	Research only just started on the necessary components. A major investment commitment.
<b>Combustion</b>				
Coal and oil mixtures used as boiler fuel	Combustion of all coals.	Simplifies use of poor-quality coals. Cuts potential oil use by 40 to 50 percent.	Although this technology sharply cuts growth in oil use, oil consumption will still increase. Adds to fuel supply complexities.	Technology currently available.
Coal blending/cleaning plants	Processing of all coals.	Reduces share of noncombustibles, pollutants, improves efficiency of coal usage.	Boosts cost of coal. Limited application to high-ash or lignite coals, such as Ekibastuz or Kansk-Achinsk.	Technology not very complicated, but Soviets apparently must import Western plants for high-quality equipment.
Coal use in small-to-medium-size power plant boilers (up to 500 MW)	Combustion of all coals.	Combustion systems "more forgiving" of poor-quality coals. Smaller initial investment, shorter construction times.	If widely applied because of poor economies of scale, total investment is likely to be greater than with large plants. Currently not receiving backing by power plant design bureaus or Gosplan energy experts.	Technology currently available.
Fluidized-bed combustion	Most coal-fueled boilers.	Increase fuel-use efficiency, flexibility to burn coals of varying quality, reduced emissions, a solid waste that is easier to dispose of and potentially lower plant investment.	Must compete with proven conventional boiler technology. Requires development of support industries to supply "bed" materials.	Soviets have done little research. Western development has yielded workable small-to-medium size application but is stalled in the scale-up to power plant boiler size.
Magnetohydrodynamics, coal fueled	Potential for major efficiency gains in coal combustion.	Applications for power plants could provide lower cost electricity with reduced environmental impact.	Very substantial investment in R&D and test facilities required.	Required breakthroughs in high-technology work on plasmas, high-temperature metallurgy, cryogenics.
<b>Synfuel</b>				
Coal pyrolysis yielding synthetic liquids and semicoke.	Lignite coals, such as Kansk-Achinsk.	The semicoke product can be transported easily.	The pyrolysis process has low liquid yield; semicoke has poor combustion characteristics, high nitrogen (pollutant), and cannot be used as a substitute for metallurgical coal.	Soviets currently operating commercial demonstration plant. Western technology based on pyrolysis of many different inputs (coal, oil, shale, tar sands) widely available.

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Technology	Applications	Advantages	Drawbacks	Status of Soviet and Western Technology
Thermocoal	Lignite coals with high moisture content.	Nearly doubles heating value, from 3,500 to 6,400 kilocalories per kilogram.	Thermocoal must be transported in semiclosed railroad cars and covered with an oil-based emulsion. Railroad transport of large volume of solid product still required.	Soviets probably operating small pilot plant. Press reports indicate that designs have been completed for 100- to 300-ton-per-day facilities.
Coal gasification	Most coals.	The product, a synthetic gas of low-to-medium energy value, can be used directly in boilers or as a feedstock for further processing into petrochemicals.	Competes with the much lower cost natural gas. Existing processes work poorly with low-quality coals.	Soviet technology at the R&D stage. No known Soviet facility. Western technology proven at commercial-demonstration plants (200 to 600 tons per day of coal input).
Direct liquefaction of coal	Processes work best with good-quality coal, but most coals could eventually be used. Soviet effort directed primarily at Kansk-Achinsk basin.	Can yield a variety of valuable synthetic liquid, petroleum, and petrochemical products for domestic use or for export.	Investment is the largest constraint—about 5 billion rubles for a facility to process 3 million tons per year of synthetic liquids. A major commitment in research resources, particularly top engineering personnel, is needed.	Soviet technology at low level. Inefficient, 5-ton-per-day plant started operating in 1984. Western technology proven at commercial-demonstration plants (200 to 600 tons per day).

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## Appendix B

### The Kuznetsk Coal Basin

Increased output from the Kuznetsk coal basin probably will be necessary to offset production declines at several coal basins in the European USSR. Kuznetsk coal will be particularly important as a replacement for coal from the Donets basin, the principal producer of Soviet high-grade steam and coking coal. According to Soviet press reports, the Kuznetsk coal basin already provides about one-third of the coking coal produced in the USSR. The Soviet media repeatedly emphasize that more Kuznetsk coking coal needs to be delivered to the Ukraine and Moscow regions. Kuznetsk coal would also be an acceptable substitute for Donets steam coal: it has a relatively high heating value of about 5,500 kilocalories per kilogram (kcal/kg), a low sulfur content (about 0.5 percent), and a low ash content (15 to 20 percent). [ ]

The Kuznetsk coal basin has the reserve base to sustain increased production over the long term. Soviet technical journals report that the basin has over 117 billion tons of economically exploitable reserves. Moreover, the reserve base for strip-mining operations is reportedly adequate to support production at the target rate for at least 70 years. Operation of surface mines is much more productive and less labor intensive than underground mining. [ ]

Despite the relatively high quality and vast abundance of Kuznetsk coal and the reported emphasis on using it to offset declines in the availability of Donets coal, output in the Kuznetsk basin has been lagging since 1975. After reaching 149 million tons a year in 1979, output fell to 144 million tons in 1981 and then rose slightly to an estimated 147 million tons in 1983. We attribute sluggish production at Kuznetsk primarily to labor shortages, delays in the commissioning of new mines, and transportation bottlenecks. [ ]

Press reports indicate that in 1982 the Soviets—concerned over production shortfalls—advanced the timetable for the startup of construction of new mines

in the basin. Soviet press reports [ ] indicate that the Bachatskiy surface mine is being expanded and two new surface mines—Talda and Urop-Karakhan—are being developed. The Soviets estimate ultimate annual potential output from these mines at about 120 million tons of coal per year. [ ]

We believe, however, that inadequate railroad capacity will be a major obstacle to expanded production at the Kuznetsk basin during the late 1980s and 1990s. A Soviet technical journal recently indicated that the “realization of increased output from the Kuznetsk basin is closely connected with a resolution of the transport problem.” A 1983 Soviet press report also complained that an imbalance between coal production and available transportation was constraining coal production in the Siberian coal basins. [ ]

Of the three major railroads that run from the Kuznetsk basin to the Ural region and to the central portion of the European USSR, only two—the Trans-Siberian and South Siberian Railroads—are used for hauling coal. The Central Siberian Railroad was built for haulage of agricultural products and lacks the necessary heavy-duty track and roadbed required for coal transport. A recent Soviet technical journal reports that increased production at Kuznetsk will require either the construction of special railroads for coal haulage or “reconstruction” of the Trans-Siberian Railroad. (Some segments of the Trans-Siberian Railroad are presently in need of major repair.) Moreover, increasing the frequency of trains and running longer unit trains with heavier loads would also require replacing the 65-kg/m (131 lb/yd) rail with 75-kg/m (151 lb/yd) rail. [ ]

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Even if track is improved, the capacity available for transshipment of coal on the Trans-Siberian Railroad could decline because of competition for transportation services as new industries are established farther to the east near the BAM. The Trans-Siberian Railroad is the only heavy-duty railroad providing a direct connection between the BAM and the central regions of the USSR. Although resource development will probably be slow, Moscow has indicated a willingness to push forward with development of timber, iron ore, phosphate, copper, and asbestos deposits in the regions flanking the BAM. [ ]

### A Place for Coal-Slurry Pipelines?

Coal-slurry pipelines are a practical alternative to railroad bottlenecks. According to Soviet coal-industry journals, the capital investment required for a coal-slurry pipeline to transport coal from the Kuznetsk basin to the Urals would be only about 50 percent of that needed to finance construction of a new railroad. In addition, Soviet estimates indicate that operating costs for a 2,000-km, 25-million-ton-per-year coal-slurry pipeline would be about 6 rubles per ton compared with 10.5 rubles per ton for transport of Kuznetsk coal by rail. Because most of the coal-slurry pipeline system would be automated, its operation would require only about 5 to 10 percent of the personnel required for railroad operation and maintenance. The use of slurry pipelines would also substantially alleviate shortages of railcars for hauling coal from other deposits and ease the strain on railroad traffic capacity. Soviet press statements indicate that the use of a coal-slurry pipeline to transport 3 million tons annually would supplant the daily dispatch of two railroad unit trains of about 80 railcars each. [ ]

The Soviets face new technological challenges in the construction and operation of long-distance, large-capacity coal-slurry pipelines. Thus far they are only operating two short (10 to 15 km) coal-slurry pipelines in the Kuznetsk basin. One transports coal to a power plant at Belovo and another to a metallurgical plant at Kuznetskiy. For these pipelines, the coal-to-water ratios are 1:7 and 1:12, respectively, and the "particle size" for the coal is in the range of 50 to 100

millimeters (mm). For the long-distance, large-capacity pipelines, in contrast, the particle size of the coal must be very small—well below 1 mm—and the concentration of solids in the slurry mixture is usually 50 percent or greater [ ]

During 1986-90, the USSR plans to build a 250-km, 3-million-ton-per-year coal-slurry pipeline—a prototype line with a coal-to-water ratio of 65 to 70 percent—from the Belovo mine in the Kuznetsk region to a power plant under construction at Novosibirsk [ ]

Although the Soviets have been working on developing coal-slurry technology since 1978, they lack necessary expertise and experience in all three major aspects of systems that supply slurry for direct-burning—creating, moving, and burning the coal slurry. Direct-burning technology is state of the art, and long-distance transport of a 70-percent slurry has not been demonstrated anywhere on a commercial scale (see table). [ ]

According to a Soviet technical journal, the Ministry of Heavy Machinery is making only halfhearted attempts to develop reciprocating, positive-displacement pumps suitable for coal-slurry pipelines. Moreover, in 1984 the Ministry proposed serial production of a coal-slurry pump despite testing results that indicated serious shortcomings. [ ]

the USSR is probably not capable of building reliable coal-slurry pumps with seals that can withstand the abrasiveness of coal slurry over the long term. The USSR is currently negotiating to obtain licenses for the manufacture of coal-slurry pumps designed by firms in West Germany and the Netherlands. [ ] the USSR probably cannot manufacture ball mills capable of grinding coal to the proper particle-size distribution.\* [ ]

\* The operational parameters of the pipeline and pumps are based on the flow characteristics of the slurry, which are ultimately determined by the coal-to-water ratio and particle-size distribution. A slurry pipeline operating in the United States was plugged twice (in one case the length of the plug was about 12 meters) by a slurry with particle sizes slightly larger than planned. [ ]

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We believe that substantial Western assistance will be necessary for successful development of the pilot project. In August, the USSR contracted the Italian firm Snamprogetti SpA to provide process technology and engineering services for creating the coal slurry for the Belovo-Novosibirsk pipeline. Some press reports indicate that a US firm has been contracted to provide assistance in construction of the pipeline and pump stations. We estimate that the value of the equipment and technology orders to Western firms will be about \$100-200 million. [ ]

[ ] the USSR is also negotiating with Western firms for the construction of a plant to produce the required chemical additives.<sup>9</sup> If the Soviets were to purchase the chemicals rather than build a plant, the

<sup>9</sup> Because 70-percent coal slurries travel at relatively slow speeds, chemical additives—although they account for only 1 percent of the slurry mix—are necessary to prevent settling of the coal. [ ]

annual cost for the chemical additives for the Belovo-Novosibirsk coal-slurry pipeline would be about \$20 million. [ ]

The cold winter temperatures in Siberia will have to be taken into account but probably will not impede pipeline operation. A coal-slurry pipeline in the United States operates regularly during the winter with air temperatures often below zero degrees Fahrenheit. [ ]

[ ] burying the pipe 2 meters will probably be adequate protection against cold temperatures and freezing. [ ] prevention of freezing could require special precautions at the slurry-preparation facility, pumping stations, and power plant—especially if a prolonged shutdown occurs. [ ]

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**Table 2**  
**Conventional Versus Direct-Burning**  
**Coal-Water Slurries**

Conventional (50 percent coal)	Direct-Burning (70 percent coal)
Technology is proven on a commercial scale.	Technology is unproven for long-distance pipelines. Potential problems with settling of larger particles, degradation of the chemical additive, and wear of burner nozzles.
Capital cost is about the same as for direct-burning system.	Capital cost is about the same as for conventional system.
Low operating cost.	Operating costs are nearly twice as high as for conventional system because of cost for chemical additives.
Requires dewatering.	Does not require dewatering.
Little volume control.	Substantial volume control.

in a slump and coal-slurry pipeline technology is still unproved on such a scale, we believe that the USSR would not build these pipelines until the 1990s at the earliest. [ ]

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Variations in terrain elevation should pose no major obstacle to operation of the Belovo-Novosibirsk coal-slurry pipeline. A profile of the route indicates that the pipeline will traverse relatively flat terrain. Some of the steepest gradients are about 2 degrees. In contrast, the steepest gradient for a coal-slurry pipeline operating in the United States is about 18 degrees. The US pipeline traverses generally rough terrain, some of which is mountainous. [ ]

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#### Future Slurry Pipeline Plans

The Soviet press has reported plans to build coal-slurry pipelines with capacities of about 15-25 million tons per year. Eventually, the Soviets probably hope to use slurry lines to supply coal to a variety of consumers. [ ]

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[ ] the USSR may build a coal-slurry pipeline to the Black Sea and export the product to Western Europe. The slurry would be shipped by tanker almost like a liquid. Because energy prices are

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## Appendix C

### The Ekibastuz Coal Basin

The Soviets estimate that economically exploitable coal reserves at Ekibastuz and the nearby Maykuben deposits amount to about 15 billion tons, nearly 9 billion tons of which have been confirmed through exploration. Given the ultimate annual output planned for Ekibastuz-Maykuben—150-170 million tons—the proven reserves would last for at least 50 years. Statements by coal industry officials indicate that they do not expect Ekibastuz-Maykuben output to reach this level until the mid-1990s at the earliest. The success of the effort to double output in the Ekibastuz region in the next decade would require improvements in both the production and operation of mining equipment and in combustion equipment.

Moscow plans to eliminate bottlenecks in the production of surface-mining machinery when an equipment plant in Krasnoyarsk comes on stream. At projected capacity, this equipment manufacturing plant is supposed to provide for the planned surface-mine expansion at Ekibastuz and in Siberia. The Krasnoyarsk plant, however, is just starting operation of the first of many production lines. Imported equipment will continue to be necessary for mine operation, at least through the 1980s. At present, for example, one-third of Ekibastuz output depends on East German excavators.

The Ekibastuz coal basin has two operating mines, Bogatyr' and Severnyy. These mines produced about 50 million tons and 24 million tons of coal, respectively, in 1984. Soviet plans for 1990 call for expansion at Severnyy and construction of a new mine, Vostochnyy. Ekibastuz coal output is to increase to 105-115 million tons annually when these plans are implemented. Overburden removal was still at an early stage at Vostochnyy, and the mine is several years from achieving initial production goals.

#### Bogatyr'

In June 1983 imagery, we saw a 13-million-ton-per-year East German bucket-wheel excavator being assembled. According to the Soviet press, this excavator will be the last one delivered to Bogatyr'. There are 11 similar excavators already in service.

the excavators were idle, apparently because of a lack of railcars for loading. Railcar shortages are a constant problem, according to press reports of complaints by the crews operating the excavators.

The bottleneck in the rail transport of coal appears to be in the failure to unload coal at its destination.

excessive numbers of fully loaded coal cars standing in the marshaling yards and at the Ekibastuz Gres 1 power plant.<sup>10</sup> According to the Soviet press, power plants burning Ekibastuz coal operate so erratically that they cannot use existing allotments and frequently cancel or delay additional orders. The coal, therefore, remains in the railcars, backing up the rail system.

#### Severnyy

In June 1982 there were nine bucket-wheel excavators at Severnyy; none were added in 1983. In their mining journals, the Soviets have discussed a program to modernize the Severnyy mine. This would probably entail additional excavating equipment. In June 1983, however, no new excavators were being assembled,

several bucket-wheel excavators were idle. Mining activity at that time was limited to overburden removal by power shovels. the producing area of this mine has changed little since 1978.

<sup>10</sup> Gres is a Soviet acronym for *gosudarstvennaya rayonnaya elektro-stantsiya* (state-regional power plant).

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**Vostochnyy**

This mine is the newest in the Ekibastuz basin and apparently is still limited to small-scale coal production. In early 1984 the Soviets reported that Vostochnyy's first stage would produce 7.5 million tons in 1985 and that bucket-wheel excavators had begun to arrive. [redacted] however, no bucket-wheel excavators were seen. Mining activity was confined to a very small section of the coal seam where five power shovels removed overburden.

[redacted]

**Utilizing Ekibastuz Coal**

The Soviets classify Ekibastuz coal as a high-ash, subbituminous fuel. This coal is a problem fuel for consumers: the ash content (noncombustible matter) can range from 40 percent to nearly 60 percent, and the energy value is only about 3,500 kcal/kg. The marked contrast between the high ash content of Ekibastuz coal delivered to power-plant customers and the inherent ash content contained in the coal

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seams (averaging about 40 percent) suggests that mining operations are slipshod or that mining techniques are not sufficiently discriminating. The high ash level is undesirable because it accelerates wear on coal-handling equipment such as pulverizers, increases the chance that equipment failure will force power-plant boiler shutdown, and adds to the transportation burden of railroads and conveyor systems. The low heat content of Ekibastuz coal (about half that of the highest quality Soviet coal) means that the entire combustion system of the consuming plant must be larger and more durable than a system of equivalent capacity at a plant fueled with a better coal. These requirements boost the investment cost for new plants and lengthen their construction time.

Ekibastuz coal is used solely as a boiler fuel, primarily in power plants. The Soviets plan to concentrate Ekibastuz coal usage through the early 1990s at five 4,000-MW power plants, four of which are being built close to the mines. The fifth plant is sited in southern Kazakhstan. The boilers at these plants are to be specially configured to deal with the technical properties of Ekibastuz coal.

The first 4,000-MW power plant, Ekibastuz Gres 1, was finished during 1984. The construction sites of the other four plants in the series shows that one plant located adjacent to Gres 1 and the plant in southern Kazakhstan are still several years from the completion of initial generating units and that work on the remaining two plants has only just started. At the planned operating rate, each of the five plants in the series would use nearly 16 million tons of coal annually to produce about 24 billion kilowatt-hours of electricity. The actual output rate at Gres 1, however, is substantially lower. Soviet press reports complained that units at this plant have operated at only one-half to two-thirds of capacity during the four years since the initial 500-MW unit went on line.

major problems have affected plant operations—four of the seven units completed by that time were shut down.

Moscow is attempting to improve Ekibastuz power plant performance through action on two fronts, coal blending and boiler upgrading. Coal blending would help operations by eliminating boiler breakdowns caused by the arrival of exceptionally poor-quality coal. Blending plants will mix better quality coal with poorer quality coal to assure a predictable, albeit low-quality, boiler fuel.

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In the late 1970s the Soviets tried to build a plant (based on their own designs) to blend or clean Ekibastuz coal. This plant was abandoned before construction was completed. Moscow now hopes that coal-blending plants from West Germany and Italy will do the job. Two have already been purchased, and eight are under negotiation. Successful operation of these Western-manufactured plants could sharply improve power plant performance.

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The boiler upgrading work is aimed at improving equipment so that coal with an ash content of up to 51 percent can be handled without stoppages. This research is, however, still at an early stage according to a September 1984 article in a Soviet power-equipment journal. Given the usual Soviet lags between research and development and introduction on a commercial scale, this new technology may not be available until the mid-1990s. It is likely, therefore, that the new technology will not be available until the third or fourth Ekibastuz Gres power plant is built. Alternatively, the Soviets may elect to delay construction of the latter two power stations until they have a boiler technology appropriately matched to the coal being delivered.

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## Appendix D

### The Kansk-Achinsk Coal Basin

Kansk-Achinsk is the largest coal basin in the Soviet Union. According to Soviet coal-industry journals, the basin contains about 600 billion tons of lignite, of which 140 billion tons are stated to be recoverable by surface-mining methods. Because of the basin's enormous reserve base, Soviet energy planners have considered it a major potential source for electric power to the western regions of the USSR. [ ]

The high moisture content of Kansk-Achinsk coal (about 40 percent), low heating value (3,300 kcal/kg), and variable physical and chemical characteristics, however, make its direct shipment by railroad to power plants in the western USSR uneconomical. Kansk-Achinsk coal is subject to spontaneous combustion in storage and transit and tends to freeze together in cold weather, making it difficult to handle. [ ]

The USSR decided to step up development of the Kansk-Achinsk basin in the late 1970s. Annual output has increased from 28 million tons in 1975 to an estimated 45 million tons in 1984. [ ]

[ ] four mines in the basin are currently producing: the Irsha-Borodino mine, the largest, accounting for about half of the basin's total output; Nazarovo 1 and 2; and the Berezovskoye mine, which is in the early stages of development. [ ]

The Soviet press reports plans to produce about 70 million tons of lignite from the Kansk-Achinsk basin in 1990 and to increase output to 170-200 million tons per year by 2000. To attain the latter rate of output, the Soviets plan to develop two new surface mines, Irsha-Borodino 2 and Uryup 1. Eventually they plan to increase annual output from the basin to 350 million tons by developing three additional mines—Berezovskoye 2 and Itatskiy 1 and 2. [ ]

#### What To Do With the Coal?

The low energy content and physical properties of the coal limit the economically effective radius for rail shipment to 1,500 km—400 km short of major

demand centers in the Urals and 2,000 to 3,000 km short of the central regions of the European USSR. Proposed solutions for rapid development of the Kansk-Achinsk basin have involved two general approaches:

- Extracting the energy content of the coal in power plants near the mines and transmitting the electricity to the western USSR over very-high-capacity, UHV powerlines.
- Upgrading the coal quality through processing in facilities near the mines and transporting the resulting semicoke, thermocoal, or liquid fuel to the western USSR.

The first approach, which began to be stressed in the mid-1970s, has received the lion's share of attention and funding thus far. [ ]

#### Status of Power Plant Construction

According to recent Soviet press reports, the Soviets plan to build two or three large, coal-fired, mine-mouth power plants at Kansk-Achinsk by 1995. Each power plant, which will reportedly be equipped with eight 800-MW units (boiler plus steam turbine-generator set), could sustain a demand for about 25 million tons of Kansk-Achinsk coal annually. These plants, however, are far behind schedule and are beset with many unresolved problems. [ ]

The first plant is currently under construction at Berezovskoye. Construction has been slow and plagued with delays [ ] On the basis of progress in the construction of the smokestack and the pace of boiler construction at other large Soviet power plants, we estimate that the first 800-MW generating set at Berezovskoye could begin operation in 1987—four years behind schedule—if everything goes well. In view of the construction history at Berezovskoye, however, we believe that the first generating set will probably not become fully operational until 1988-89. The 800-MW unit is essentially a prototype unit that

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has not been field-tested. At least two to three years probably will be required to discover and correct problems before the unit can operate satisfactorily.

[redacted]

There is at least a possibility that the Soviet-designed 800-MW unit may never operate satisfactorily and that Moscow may have to scale back plans for burning Kansk-Achinsk coal at large, mine-mouth power plants:

- The Soviets have never successfully operated an 800-MW coal-fired boiler [redacted]  
[redacted] the two 800-MW units built during the

late 1960s and early 1970s were later converted to burn fuel oil.<sup>11</sup> A major problem with the 800-MW coal-fired unit was that the high combustion temperature caused melted ash (slag) to build up on the inside surfaces of the boiler, eventually forcing a shutdown.

- Soviet attempts to burn Kansk-Achinsk coal in a 500-MW boiler at Nazarovo ended in failure. Press reports indicate that the unit was down a total of

<sup>11</sup> Although the Soviets commissioned eight 800-MW generating sets between 1975 and 1982, all were designed to operate on fuel oil or natural gas. [redacted]

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three years during the first five years of operation.

the 500-MW unit was later replaced with a much smaller unit using different combustion technology.

The construction history at Berezhovskoye, the lack of a successful prototype, Soviet press reports alluding to unresolved technical problems, and the fact that the Soviets are now attempting to develop a new type of combustion technology for Kansk-Achinsk coal all strongly suggest that the power plant may not operate satisfactorily when completed.

A pilot boiler that reportedly will be used at Kansk-Achinsk is currently under development. The boiler—which uses swirl-combustion technology to fire at a lower temperature than the boilers being installed at Berezhovskoye—does not melt the ash and consequently avoids most of the slag buildup problem. This technology also permits a substantial reduction in the boiler's size and, probably, a reduction in investment cost. The commercial-demonstration units have capacities ranging from 50 to 100 MW. Scaling up the new design will, however, present considerable engineering problems that must be solved before the technology can become a major factor in development of the Kansk-Achinsk basin.

#### Development of Synfuel Technology

Although the USSR has conducted coal synfuel research since the early 1950s, the Soviets—like Western energy experts—probably began to view synfuels as a realistic option only in the 1970s. We believe that the recognition of increasing oil production costs and the slowing growth in Soviet oil production has led to increased interest and funding for USSR synfuel research. The Soviet coal synfuel effort is directed primarily at the potential for liquefying Kansk-Achinsk coal. The coals at Ekibastuz (too high in ash content) and Kuznetsk (good in quality and needed for other uses) are currently not being viewed by the Soviets as candidates for synfuel projects.

Although liquefaction technology has been successfully developed in the West, this technology has been temporarily shelved due to the currently low price of crude oil relative to the high costs of constructing and operating a liquefaction facility. Western estimates

indicate that plants to produce 5 million tons of synthetic liquids per annum would cost about \$4-6 billion per plant. The production costs—including capital charges—are estimated at roughly \$40 to \$50 per barrel.

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#### Soviet Progress in Coal Liquefaction

Earlier Soviet plans called for the large-scale production of either semicoke or thermocoal.<sup>12</sup> In 1983 the USSR completed construction (begun in 1976) of a commercial-demonstration facility at Krasnoyarsk that uses pyrolysis to process up to 1.2 million tons of Kansk-Achinsk coal per year and produce about 400,000 tons of semicoke, 54,000 tons of synthetic oil, and 120 million cubic meters of gas. Earlier media reports indicated plans to build three large-scale commercial pyrolysis facilities, each with an annual processing capacity of 25-50 million tons (input).

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We believe that the Soviets have substantially scaled down their plans for using pyrolysis.

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the research funds for the pyrolysis process were cut off in 1979. The Long-Term Energy Program, which was circulated early in 1984, indicates plans to produce semicoke only on a limited basis, from those Kansk-Achinsk coals that cause the worst boiler fouling when burned—about 8 to 9 percent of the basin's reserves. Soviet media reporting during the last few years discussing prospects for the Kansk-Achinsk basin hardly mentions pyrolysis and instead emphasizes plans for liquefaction.

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Our analysis of Soviet statements on future synfuel research suggests that the Soviets are abandoning plans for using pyrolysis on a large scale because the liquid yield is only about 5 percent—which, according to a Soviet technical journal, makes high-volume

<sup>12</sup> In the production of semicoke by pyrolysis, coal is heated in the absence of air to about 550 degrees Celsius, and some synthetic liquids are produced. In the production of thermocoal, the moisture is simply removed by heating the coal to about 450 degrees Celsius; most of the volatile matter that contributes to better combustion remains. Although no synthetic liquids are produced, the heating value of Kansk-Achinsk coal is increased from about 3,300 kilocalories per kilogram to about 6,400.

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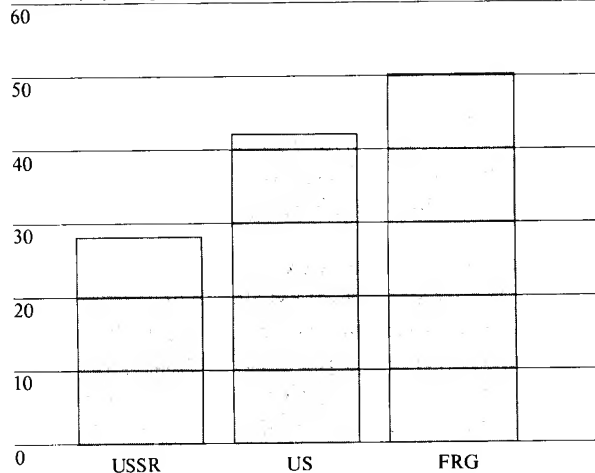
production of synthetic liquids “practically impossible.” The Soviet press reported in 1983 that a scientific committee on synfuels, subordinate to the State Committee on Science and Technology, concluded that pyrolysis cannot be used as a basis for processing Kansk-Achinsk coal into synfuels. The Soviets would still be left with the task of transporting a large volume of the solid product (semicoke) long distances in special, closed railroad cars or covered with an oil-based liquid to prevent absorption of water from rain or snow. There is some evidence to suggest that the semicoke requires high combustion temperatures (which causes the ash content to fuse into slag on the boiler walls) because most of the hydrogen and the volatile matter have been driven off in processing. In addition, Soviet press reports indicate that the semicoke contains a high percentage of nitrogen oxides—suspected to be a major contributor to formation of acid rain. [ ]

The Soviets may have pushed forward initially with pyrolysis because development of this technology probably would not have been dependent on Western assistance. The USSR has equipped the Krasnoyarsk facility almost totally with Soviet equipment and probably would not have needed Western assistance to build commercial-scale pyrolysis plants. Pyrolysis is a relatively simple process, essentially similar to the production of coke from coal but at a lower temperature. [ ]

The Soviets have probably also scaled back their plans for thermocoal production and are still uncertain about the utility of the process. No synthetic liquids are produced and the transport of a solid product is required. In 1975, a Soviet coal journal reported that a “simple and reliable” design for a 312-ton-per-hour thermocoal facility was completed. Construction of this plant has yet to begin. Indeed, in 1982 the Soviet press reported that the designing of a thermocoal plant to process 100 tons per hour was proceeding slowly because of “insufficient interest in the concerned ministries.” Although TASS has again reported that a thermocoal facility (to process 100 tons per hour of Kansk-Achinsk coal) has been “devised,” no date or time frame was given for construction—nor even an indication that construction was planned. [ ]

**Figure 8**  
**Liquid Yields From Synfuel Processes**

Percent, by weight, using dry, ash-free coal



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Analysis of recent press reports, Soviet technical journals, and the Long-Term Energy Program indicates that the USSR believes that direct-conversion (liquefaction) is a better alternative to semicoke and thermocoal. At a mine near Moscow, the Soviets are currently operating a 5-ton-per-day (input) direct-conversion pilot plant—the ST-5 facility. This plant produces 1 ton of synthetic liquids per day. Construction of the plant began in 1981 but was not completed until 1984. The plant reportedly uses an improved version of the Bergius conversion process—a technology pirated from Germany at the end of World War II. The Soviet media report plans to build a 75-ton-per-day (input) liquefaction facility at the Berezhovskoye mine in West Siberia if the process proves feasible. [ ]

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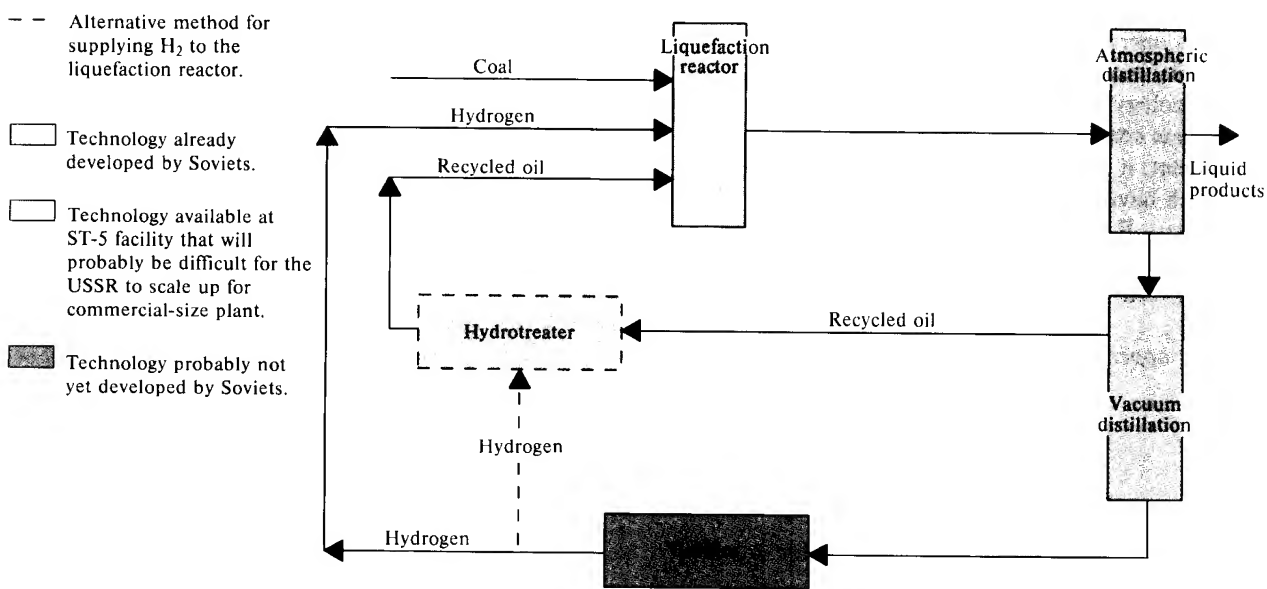
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**Figure 9**  
**Basic Liquefaction Process**



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According to the Long-Term Energy Program, during 1986-90 the Soviets will attempt to develop and perfect coal liquefaction technology suitable for large-scale production of synthetic liquids. Commercial direct-conversion facilities are to be built during the 1990s. We believe that substantial Western assistance in technology and equipment would be required to meet this goal.

no real experimental base existed in the USSR to support major West Siberian synfuel projects. The Soviet liquefaction process has a low yield—about 30 percent—of synthetic liquids, whereas the yield for most Western technologies is about 40 to 50 percent on a dry, ash-free basis (see figure 8). The Soviets' dissatisfaction with their progress is evidenced by their attempts during the past several years to solicit assistance in coal-conversion technology—primarily through technical information

exchange agreements—from West German, Japanese, Italian, and US firms. The Soviets have tried several times to license US technology.

Soviet capability to scale up the liquefaction reactor, which is essentially a type of hydrocracker, is doubtful. Soviet industry has been unable to build a reliable hydrocracker—a sophisticated secondary oil-refining unit that breaks down heavy fuel oils into lighter, more valuable products. Soviet press reports also indicate that the USSR still has not developed the technology to build a reliable gasifier (using oxygen) to provide hydrogen for the process (see figure 9).

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Most of the proven technology in direct conversion with pilot-plant operating capacities greater than 5 tons per day is of US origin. The US processes—EDS and H-coal—can work with a variety of coals, and the technology has been successfully tested with lignite-grade coals. The West German firms Ruhrkohle and Veba operate the only significant direct-conversion facility located outside the United States. Because the technology used by the West German firms cannot process coal with a moisture content greater than 14 percent, it is not adaptable to Kansk-Achinsk coals, which have a moisture content ranging from 32 to 45 percent. Ruhrkohle, however, is also a sponsor of the two US processes and, as a sponsor, has rights to the marketing of the technology. [REDACTED]

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## Appendix E

### Ultra-High-Voltage Electricity Transmission to the Urals and the European USSR

A technical challenge presented in the development of the USSR's eastern coal basins—notably Ekibastuz and Kansk-Achinsk—is the economical transfer of large amounts of coal-derived energy over long distances. Soviet planners view the Ekibastuz energy complex as a source of electricity not only for the rapidly growing demand in Kazakhstan but also for Central Asia, West Siberia, the Urals, and parts of the European USSR. The complex of Ekibastuz power plants, which will include the five large Gres plants and some smaller plants now on the drawing boards, will have a capacity of nearly 40 million kW and generate 220 billion kilowatt-hours (kWh) annually. Consumers in Kazakhstan are scheduled ultimately to receive 100 billion kWh; 80 billion kWh is slated for other areas of Central Asia and parts of West Siberia; and 40 billion kWh is to be distributed to the Urals and farther West. [ ]

Ultra-high-voltage (UHV) electricity transmission provides—in theory—an efficient solution to the energy-transfer problem. Mine-mouth power plants can be linked via UHV transmission lines to distant consumers, eliminating congestion of rail lines and providing a highly usable form of energy. The UHV transmission systems needed at Kansk-Achinsk and Ekibastuz, however, call for technical development that equals or exceeds that in use anywhere in the world. Current goals call for connecting Ekibastuz with substations in the Urals, using 1,150 kilovolts (kV) alternating current and with Tambov, south of Moscow, using 1,500 kV direct current. [ ]

Moscow has given a higher priority to the work on the 1,500-km Ekibastuz-Urals 1,150-kV transmission line because segments can be put into service incrementally. The western section leading to the Urals is under construction and will connect a transformer substation at Ekibastuz with substations at Kokchetav, Kustanay, and Chelyabinsk. Transmission-line towers have been erected and conductor cable has been

strung between Ekibastuz and Kokchetav and between Kokchetav and Kustanay. According to the Soviet media, the Ekibastuz-Kustanay portion of the line is energized at 500 kV [ ] We estimate that the entire line, with appropriate transformers and switching equipment for full-capacity operation, will not reach Chelyabinsk until the late 1980s. Another 1,150-kV line to West Siberia is likely to be finished shortly thereafter. [ ]

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The Soviets have held up construction of transformer substations on the eastern segment of the 1,150-kV line from Ekibastuz to Itatskiy, near Kansk-Achinsk. This transmission line was designed for both short-term and long-term applications. It will be used initially to supply electricity from Ekibastuz power plants to the constructors of the Kansk-Achinsk power plants. Eventually, when several of the large power-generating units at Kansk-Achinsk are brought on line, the direction of power flow can be reversed and tied in to the Urals demand center using transformer and switching connections at Ekibastuz. [ ]

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The 1,500-kV direct-current transmission line is the UHV option that would give the Soviets the capability to move electricity the longest distances. Plans for this line call for transmission of power a distance of 2,414 km from Ekibastuz to Tambov [ ]

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[ ] that most of the work on the line ceased after June 1982—reportedly because of funding cuts. [ ]

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#### UHV Applications

UHV electricity transmission (where line potentials reach 800,000 volts or more) was developed primarily to meet two needs of electric power networks: large transfers of power and minimal losses over long distances. Designs for UHV systems must take into account other factors such as reliability, stability,

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controllability, environmental impact, and safety—requirements that are common to power systems of all voltages. Transmission at higher voltages is advantageous because the electrical transmission capability of a powerline increases approximately as the square of voltage, while total cost increases at a lower rate. In addition, the line losses per unit of power-generating capacity (which increase as a function of distance) are usually smaller with higher voltages.

**UHV Operations**

Most UHV systems, in operation or proposed, use alternating-current (AC) technology. In a UHV-AC

system, electricity generated at one or more power plants travels over powerlines to a substation where transformers step up the voltage to the designated UHV level. The electricity at the stepped-up voltage is sent to another UHV substation near consumers; transformers then step down the voltage and pass the energy on to users over the existing power-distribution network. The UHV transformer substations can contain a number of medium-to-high-technology components: high-voltage switchgear, compensators to ensure synchronous operations, and equipment that

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permits automatic or remote control during normal functions or emergencies. Power systems using UHV-AC technology can be built incrementally by adding power lines and substations as electricity demand or generating capacity increases. [ ]

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While UHV-AC technology can be applied to most long-distance, large power transfers, in some circumstances UHV direct-current (DC) transmission can be advantageous. UHV-DC transmission has smaller line losses. An overall project is cheaper to build because the technology requires only two conductors per circuit instead of the three needed in AC transmission. Moreover, a UHV-DC transmission line can improve the reliability and stability of a power system because it can be more readily isolated from electrical disturbances. [ ]

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UHV-DC transmission, however, has drawbacks. A principal disadvantage of DC transmission results from the cost and complexity of the rectifier-inversion equipment needed to change the current from AC to DC and back again to AC so that it can be distributed to customers. UHV-DC transmission has been applied in the West where it is desirable to transfer a large amount of power to a single distant demand center. In these applications, the cost of the line is held down because only one set of rectifier-inversion equipment is needed. As a consequence of these equipment considerations, UHV-DC transmission lines are not tapped along their route, and the whole line plus terminal converter stations must be operational before any power can be transferred. [ ]

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